

## Rubric for Cosmology Concept Map

Components	Exceptional (5)	Satisfactory (3)	Deficient (1)
<b>Age of Universe</b>	<ul style="list-style-type: none"> <li>•13.7 billion years</li> <li>•Determined from Hubble constant—work backwards from present rate of expansion</li> </ul>	Mentioned	Missing or incorrect
<b>Evidence for a beginning</b>	<p>Hubble constant</p> <ul style="list-style-type: none"> <li>•CMB: predicted by Gamow; relic from 380,000yrs after Big Bang; when universe cooled, neutral atoms formed and the universe became transparent; matches black body spectrum from hot early universe</li> <li>•Ratios of elements (nucleosynthesis): predictions of ratios from nuclear physics match observed ratios</li> <li>•Redshift of distant galaxies suggest expansion—Hubble's Law (redshift is proportional to distance)</li> <li>•expansion after a big bang is consistent with general relativity, our best theory of gravity</li> <li>•evolution of galaxies: older galaxies have different (less ordered) structure</li> <li>•evolution of stars: stars from long ago were composed of lighter elements; there</li> </ul>	Mentioned	Missing or incorrect

	are generations of stars		
<b>Timeline of major events in Universe</b>	<ul style="list-style-type: none"> <li>•Big Bang (<math>t=0</math>)</li> <li>•Planck epoch (<math>t&lt;10^{-44}s</math>)</li> <li>•Inflation (<math>10^{-37}&lt;t&lt;10^{-12}s</math>)</li> <li>•Birth of elements (nucleosynthesis)</li> <li>•Quark-gluon plasma (<math>t=10^{-12}s</math>)</li> <li>•Anti-matter annihilates with matter (<math>t=10^{-4}s</math>)</li> <li>•Baryons form</li> <li>•Nucleogenesis (<math>10^2s</math>)</li> <li>•Neutral Atoms form (380,000 yrs): surface of last scattering, source of CMB</li> <li>•First stars form (<math>10^7</math> yrs)</li> <li>•First galaxies form (<math>10^8</math> yrs)</li> <li>•solar system forms (<math>9 \times 10^9</math> yrs)</li> <li>•acceleration of expansion begins (<math>t &gt; 1.2 \times 10^9</math> yrs): dark energy dominance</li> </ul> <p>Timeline of major events in Universe: (Carl Sagan)</p> <p>Big Bang Jan. 1</p> <p>Nucleosynthesis (elements) Jan. 1</p> <p>First star Jan. 1 (10 AM)</p> <p>Galaxies May. 1</p> <p>Solar system Aug. 30</p> <p>Life on Earth Sept. 28</p> <p>First animals Dec. 16</p> <p>Animals colonize land Dec. 20</p> <p>Extinction of dinosaurs</p>	Mentioned	Missing or incorrect

	Dec. 29 Human beings Dec. 31 (late)		
<b>Significant Era's</b>	Lists the eras 1-4 in sequential order(Big Bang, Planck Era, formation of atoms, stars, galaxies and clusters, etc) and adds details about them. Order of the eras, Inflation, surface of last scattering, matter forms. States that universe underwent inflation and expansion and now experiencing accelerated expansion.	Mentioned	Missing or incorrect
<b>Evidence for Era's</b>	Mentions fine structure of CMB or relationship of red shift to Hubble constant Mentions freeze out of creation of heavy particles.	Mentioned	Missing or incorrect
<b>Structure of Universe</b>	Lists all the cosmic objects from our solar system on out, isotropy, clumpiness, ideas of globally homogeneous, and locally heterogenous. Mentions at least three of Bosons, Fermions, dark matter/energy and ordinary matter or states that ordinary matter is only 4% of total mass/energy.	Mentioned	Missing or incorrect
<b>Evidence for Structure of Universe</b>	Mentions that galaxies appear to be rotating too fast for the amount of matter contained or that accelerated expansion may be related to dark energy	Mentioned	Missing or incorrect

	or other specific evidence, key objects, spectral electromagnetic spectrum		
<b>Mass Energy in the Universe</b>	<p>Beginning was an extremely hot environment with intense concentration of energy</p> <p>As universe spreads it cools, and energy takes the form of matter <math>E = mc^2</math></p> <p>Theoretically should be able to convert back to energy, But before it can change back, universe has cooled too much so it stays matter</p> <p>Curvature of space, fate of evolution &amp; expansion &amp; its fate.</p>	Mentioned	Missing or incorrect
<b>Evidence for Mass Energy in Universe</b>	<p>Intensely hot, energetic environment converts energy to matter as it expands and cools.</p> <p>Early fluctuations or irregularities in these conversions became the Seeds of the Galaxy from the early universe</p> <p>Matter and antimatter unbalanced. We wind up with leftover matter. Protons, neutrons and atoms Form</p> <p>Birth of Elements: 25% Helium, 74%</p>	Mentioned	Missing or incorrect

	<p>Hydrogen, 1 % other</p> <p>Dark matter encourages clumping of atoms and the formation of first stars. Stars' fusion create the elements up until Iron.</p> <p>Dark Matter encourages star, supernovae, and galaxy formation.</p>		
<b>Nature of matter in Universe</b>	Standard model for 4% of matter, dark matter, and dark energy	Mentioned	Missing or incorrect
<b>Origin of Mass in Universe</b>	<p>Beginning...pure energy, hot and dense</p> <p><math>10^{-47}</math> sec = Planck time, no mass, no particles</p> <p><math>10^{-35}</math> to <math>10^{-12}</math> sec Inflation</p> <p>After inflation: particles, radiation, smallest atoms (H, He, Li)</p> <p>Later, when stars formed: nucleosynthesis of heavier elements up to Fe</p> <p>Supernovae explosions: elements heavier than Fe created, disbursed</p>	Mentioned	Missing or incorrect
<b>Role of Astronomy</b>	<p>Nature of Light and role of speed of light and wave nature of light</p> <p>Tools: telescopes, CCD cameras, spectrographs</p> <p>Image processing with digitized images</p> <p>Plate scale for converting to angular size</p> <p>Distance size</p>	Mentioned	Missing or incorrect

	<p>relationships with angle</p> <p>Spectra giving element fingerprint, redshift</p> <p>Distance determination: parallax shift with given baseline (closer → more parallax)</p> <p>Arcsecs, parsecs</p> <p>Inverse square law: Luminosity-Brightness relationship, <math>B = L/4(\pi)d^2 \text{ W/m}^2</math></p> <p>Standard candle measurement with Type Ia supernovae</p> <p>Exceptional</p> <p>Observations of the expansion of the universe leads to the concept of a big bang.</p> <p>Cosmologists can work backwards from observations of the visible universe to draw conclusions about the nature of the early universe.</p> <p>A cosmologist – developing a model of the universe – knows to discard models that are not consistent with astronomical observations.</p> <p>predictions of cosmic background radiation and observations of the CMB by Penzias and Wilson</p> <p>the early universe was the optimum environment to breed elements by nuclear fusion, and would</p>		
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	<p>result in the same proportion of hydrogen and helium observed today</p> <p>fluctuations in the CMB had to be at least a certain size to lead to the formation of galaxies at a certain rate</p>		
<b>Role of Particle Accelerators</b>	Controlled prediction of massive particles, not found naturally, recreating the conditions of the early universe, confriming standard model, analyzing nature's particles in a controlled environments examining particle structure, studying nucleosynthesis	Mentioned	Missing or incorrect
<b>Key Cosmology Questions</b>	What's dark energy matter, fate of the universe, charge-peraty, violation, gravitation, theory of quantum gravity, what is the big bang, planck time, are there other generations, antimatter, neutrinos	Mentioned	Missing or incorrect

<b>Relativity</b>	<p>Distinguish the difference between the Special Theory of Relativity and the General Theory of Relativity.</p> <p>Special Theory of Relativity As one moves faster: time slows down, mass increases, and length contracts.</p> <p>Gamma factor to compute the time dilation.</p> <p><math>1/\text{Sqrt}(1-v^2/c^2) = \text{Gamma}.</math></p> <p>Muons reaching the Earth's surface is an example of time dilation.</p> <p>Einstein's theory.</p> <p>Rest mass vs. Relativistic mass.</p> <p>Two based assumptions</p> <ol style="list-style-type: none"> <li>1. The laws of physics are valid regardless of the frame of reference.</li> <li>2. The speed of light is a constant regardless of the frame of reference.</li> </ol> <p>Light clock as a way of deriving the equation for gamma.</p> <p>The speed of light is an important factor in understanding why Einstein developed the special theory.</p> <p>General Theory of</p>	Mentioned	Missing or incorrect
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	<p>Relativity Einstein's theory Replaces gravity. Involves the concept of Space-Time. Mass bends light because mass causes a curvature of Space- Time. Newtonian physics mass does not attract light and bend it, since light has no mass. Importance of Eddington's observation of the Total Eclipse of 1919 to confirm the theory. Explains the reason why planets orbit the Sun. Black holes</p>		
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